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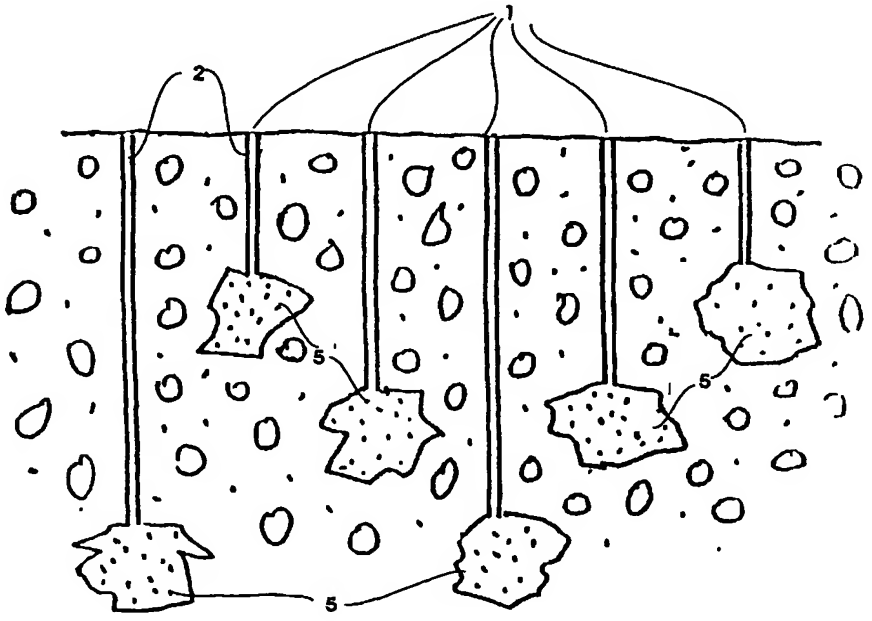
(54) Title: METHOD FOR REDUCING THE LIQUEFACTION POTENTIAL OF FOUNDATION SOILS



(57) Abstract: The aim of this invention is to present a method in which holes (1) are drilled into the ground for the injection of highly expansive grouts (5), so that the subsoil is void filled and compacted and thus the liquefaction potential under earthquake and vibration forces are reduced.

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A METHOD FOR THE REDUCTION OF LIQUEFACTION POTENTIAL OF FOUNDATION SOILS UNDER THE STRUCTURES

TECHNICAL FIELD

This invention relates to a method of reduction of liquefaction potential of foundation soils under the buildings.

STATE OF ART

Engineering structures (buildings) need a safe foundation soil, capable of carrying the loads, transferred from the superstructure. But some soils loose their bearing capacity and liquefy under earthquake loads. At the end, the buildings resting on liquefied soils are damaged and may be out of service.

Loss of shear strength of foundation soils under earthquake loads and vibrations are first referred by Japanese scientists Mogami and Kubo (1953) as Liquefaction. Following the earthquakes of Alaska and Niigata in Japan an intensive research has been carried out in the last 30 years and the term "Liquefaction" is used as a generally accepted terminology in the international earthquake literature.

When the ground acceleration reaches the foundation, an earthquake liquefaction takes place. This liquefaction causes damage to the buildings, instability of the slopes, failure of bridge or building foundations or swimming of buried engineering structures with an upward movement.

Liquefaction as defined by Mogami and Kubo is a complex process occurring in saturated cohesionless soils under untrained conditions, when subjected to monotonical transient or cyclic loads.

Increase of excess pore pressure under undrained conditions is the major factor in liquefaction.

Under statical or cyclic loading conditions dry coheisionless soils may also be subjected to settlement. Saturated, cohesionless soils decrease their volumes due to their tendency to settlement. Rapid loading and untrained conditions, cause an increase in pore pressure, resulting liquefaction.

There are two main precautions against foundation soils with high liquefaction potential. The first one is to evade any building construction on such soils. The second one is to improve the foundation soils with liquefaction potential.

The classical and common way is to order piles under the structure. In this way the foundation loads are transmitted to deeper soil layers with no liquefaction potential. Beyond the requirement that such a precaution needs heavy equipment to be used and thus costly, it also has some technical limitations. If the liquefiable soils go down to very deep elevations, the application may not be economical and/or practical. Also the behaviour of pile-structure interaction in liquefied soils is not clearly known at the present state of the art.

The most important factor in the liquefaction of soils is the loose structure of the soil. The change of soil configuration of the soil grains from loose to dense state, decreases the liquefaction potential very considerably.

With this idea, "Dynamic Compaction Method" is used, in which heavy loads are dropped on loose soils, to improve their load bearing capacities, and decrease the liquefaction potential, using very heavy cranes, which have high costs, making the compaction expensive.

Beyond that, all the previously mentioned improvement techniques require heavy machinery and they are expensive, they require large areas for their field application. Existence of buildings on the site, is another severe limitation to the use of such machinery.

THE SCOPE AND APPLICATION OF THE INVENTION

The objective of the present invention is to reduce the liquefaction potential of foundation soils under the buildings, securing their performance under static and dynamic loads.

In this context, to present a method to decrease the liquefaction potential without introducing cementitious materials into the foundation soil is aimed.

Another aim is to present a method which can be applied under new buildings as well as already existing structures, without disturbing the available facilities.

Considering this aim and other factors mentioned here, the aim of this invention is to present a method which reduces the liquefaction potential of soils by improving its characteristics.

BRIEF DESCRIPTION OF THE DRAWINGS

Additionally figures are presented to define the applications and the definitive characteristics of the invention. The figures presented lead to a better understanding of the invention, but they do not limit their field of application in anyway. The invented method may be used in many different ways.

Figure 1, gives a general view of the soil type. According to the generally accepted principals of international soil mechanics literature, soil has three

components, namely solid particles, water and air. This figure is given for granular soils, but the method of the invention can be used in any type of soil without limitation.

In Figure 2, the expansive resin is injected through the drilled holes into the soil. The injection material is pumped from a storage tank at the surface.

Figure 3, shows the replacement of air and water in the soil pores, by expansive resin.

Figure 4, and Figure 5 show the approach of expansive resin in the soil. The injection of the resin may be given, forming columns of injection as it in Figure 4, or single bulbs of resin may be formed in the soil as it is in Figure 5.

Figure 6, shows the surcharge fill, which is necessary if the injection has to be performed in the field before the building is erected. The fill supplies the overburden pressure for the compaction of injected soil. It may be removed later.

In Figure 7, the use of the building weight is shown, as an overburden for the compaction of subsoil.

APPLICATION OF THE INVENTION METHOD

In the subject method of invention, a number of holes are prepared in the soil to be injected, vertically or at various angles with the vertical. Depth of holes (1) may be different or same and also the horizontal distance between the holes may be different according to the project or soil type to be injected. Similarly as in the case of holes, the pipes (2), may be at various angles or distance from each other.

Afterwards resins with expansion capabilities of many times of its original volume is injected into the soil. They first fill the voids in the soil and then begin to expand, compacting the existing soil so that liquefaction potential is reduced to very low limits or even zero. The injection of the resin into the natural soil (4), follows the path of minimum resistance, thus filling the voids in the soil.

The injection of the resin, which may expand many times of its original volume may be formed in columns as seen in Figure 4 or in bulbs at different levels as seen in Figure 5. A planning may be performed considering the soil conditions of the site and the project, which give size and place of the resin bulbs to be formed.

The improvement of the foundation soil in this invention method is not limited with the grouting pressure, as it is the case with cementituous materials, but the chemical expansion pressure is the major factor for the neighbouring soil media also. The subsoil is first compacted under pressure and then with the effect of penetrating resin liquefaction potential is almost eliminated.

Fine grained cohesive soils which possess very low permabilities are compacted under the expansion pressure of the resins and their bearing capacity is considerably increased, reducing the liquefaction potential.

The application of the invention method at soil layers close to the surface, the compaction effect may not properly occur due to the lack of overburden pressure. This may be case of application for new constructions. Use of an extra soil fill as it is in Figure 6 satisfies the required overburden. The necessary compaction counter pressure is supplied with the load of the fill. Later on, extra fill may be removed.

If the liquefaction improvement is going to be performed under an existing building, as shown in Figure 7, such a fill as in Figure 6 is not required. The weight of the building supplies the necessary pressure balance.

For the injection of expansive resins drilling of various small diameter holes is sufficient. Thus the injection holes do not effect the statical system or the functional use of the building, and cause no reduction in the rigidity of the structure or its service.

Since an expansive pressure of 40-50 tons/m^2 is applied after the chemical reaction of the resin, the liquefaction improvement of any type of soil is possible with this system.

The effect of expansion pressure on the building foundations may be detected at the building by means of precise geodetic measurements made externally. With this purpose, measuring equipments making use of laser beams or gages which can measure small fractions of a milimeter may be used. For the liquefaction improvement of the foundation soil before the new construction, the improvement may be secured by displacement measurements made with laser beams at the close vicinity of the injection point.

The counter pressure at deeper layers is not limited with the geostatic overburden pressure at that level. The frictional forces between the soil blocks play also an important role as an extra overburden load. Thus the necessary load for the compaction may be satisfied.

Use of expansive resin is not limited with single layer soils, but it can also be applied in multi-layer soil formations. The application may be performed in single columns or at certain points as shown im Figures 5 and 6, and this gives a flexibility to the invention method.

CLAIMS

1. A method for the reduction of liquefaction potential of foundation soils, comprising the steps of drilling holes (1) at a distance to each other, and injecting expansive resins filling the voids and compacting it, thus obtaining a strong and compact foundation soil with reduced liquefaction potential.

2. The method of claim 1 wherein the holes are drilled vertically or at any angle with the vertical.

3. The method of claim 1 wherein the liquefaction potential is reduced at any depth.

4. The method of claims 1 to 3 wherein, the method is controlled by laser equipments or other sensitive measurement gages.

5. The method of claim 1 wherein the holes are drilled at any distance from each other.

6. The method of claims 1 to 5 wherein holes are drilled at the same or different diameters.

7. The method of claims 1 to 6 wherein holes are protected .

8. The method of claims 1 to 7 wherein the expansive grout is applied uniformly.

9. The method of claims 1 to 8 wherein liquefaction reduction is made at the same or at different degrees at different depths.

10. The method of any of the claims above, wherein the liquefaction reduction is made with no limitation of the depth below ground level.

11. The method of claims 1 to 10, wherein expansive grout is performed at time intervals.

12. The method of claims 1 to 11, wherein liquefaction reduction is made in any type of dry or wet clay silt sand soil or rock, or water content without limitation.

13. The method of claims 1 to 12, wherein the ground may be disturbed, remoulded by earthquake or any kind of vibration for any kind of soil or rock.

Figure 1

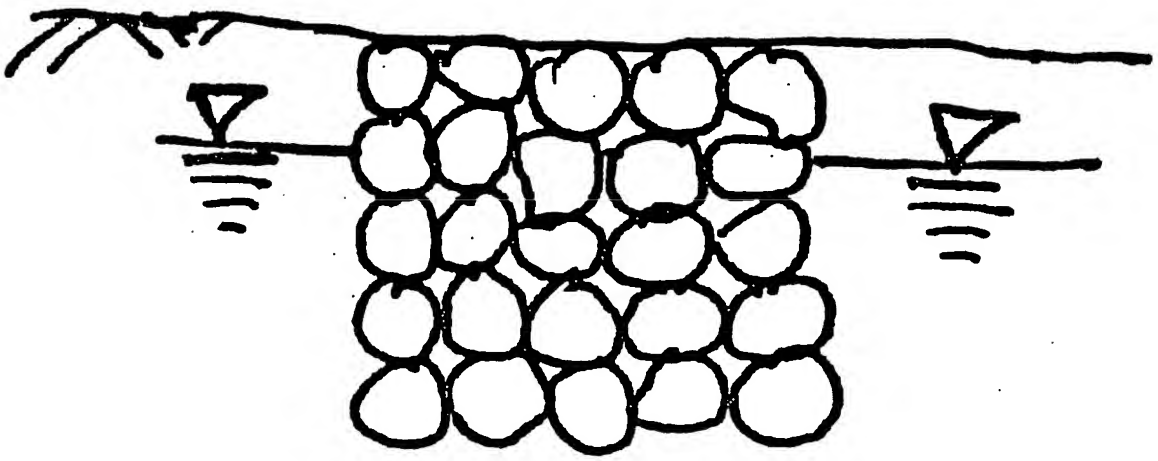


Figure 2

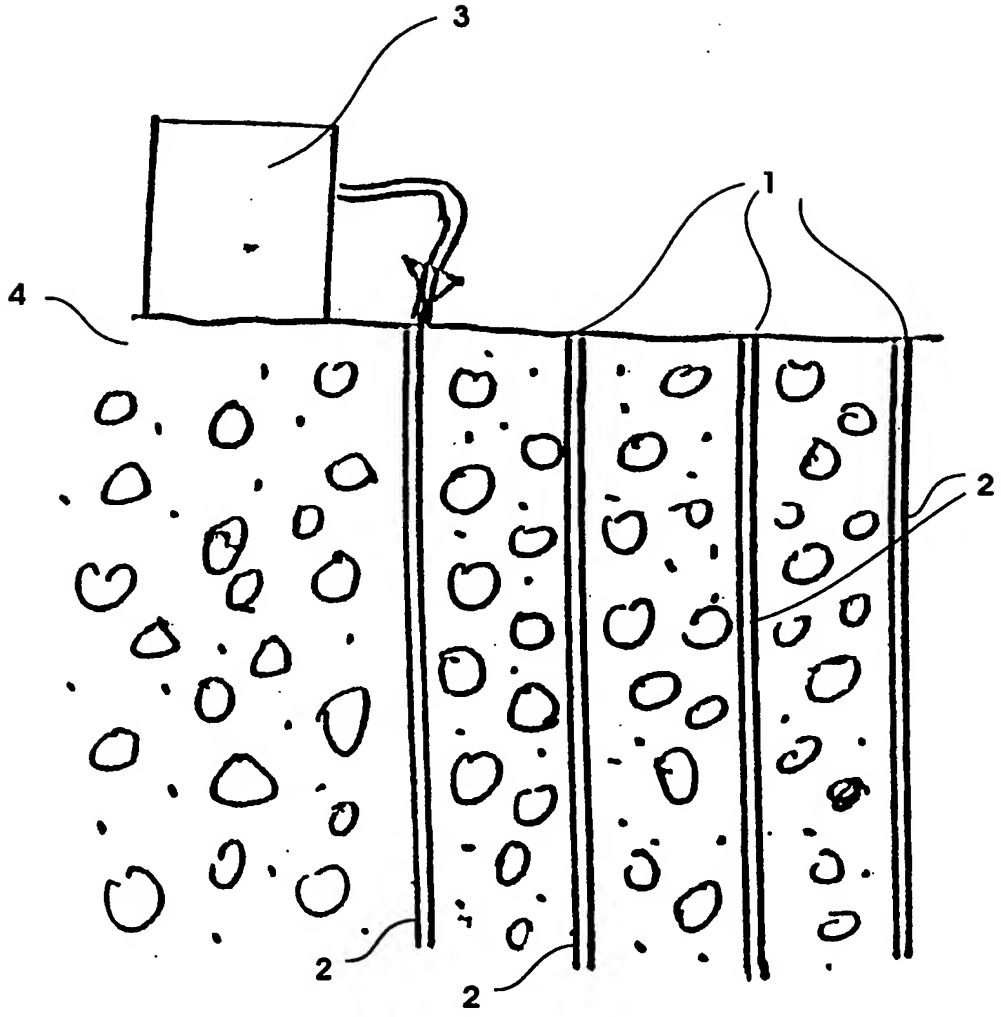


Figure 3

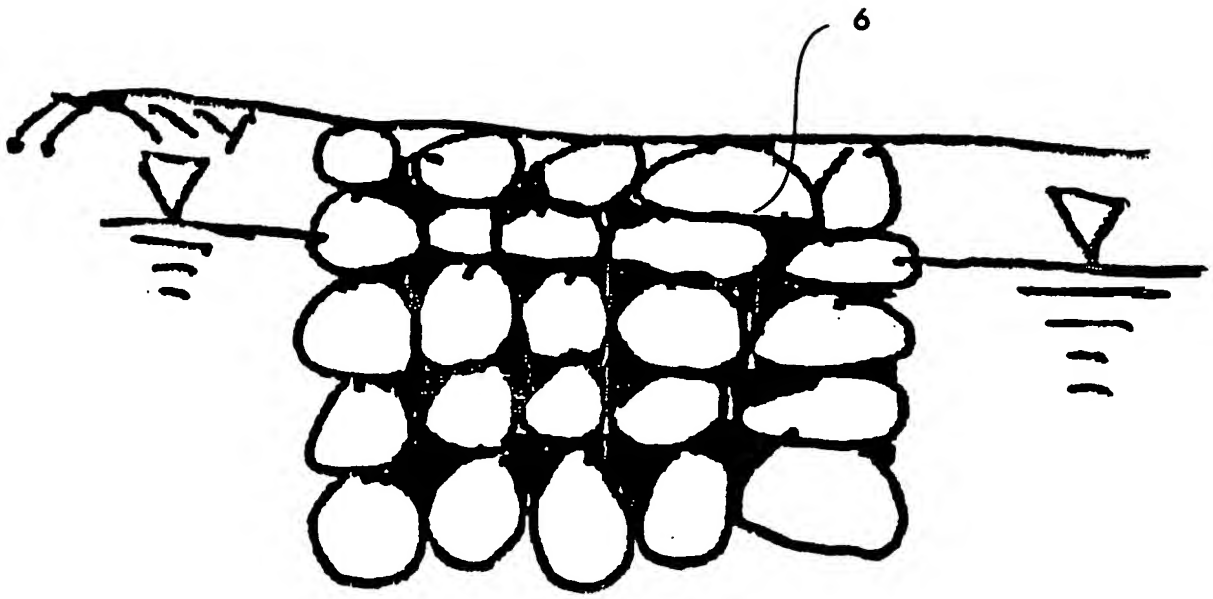


Figure 4

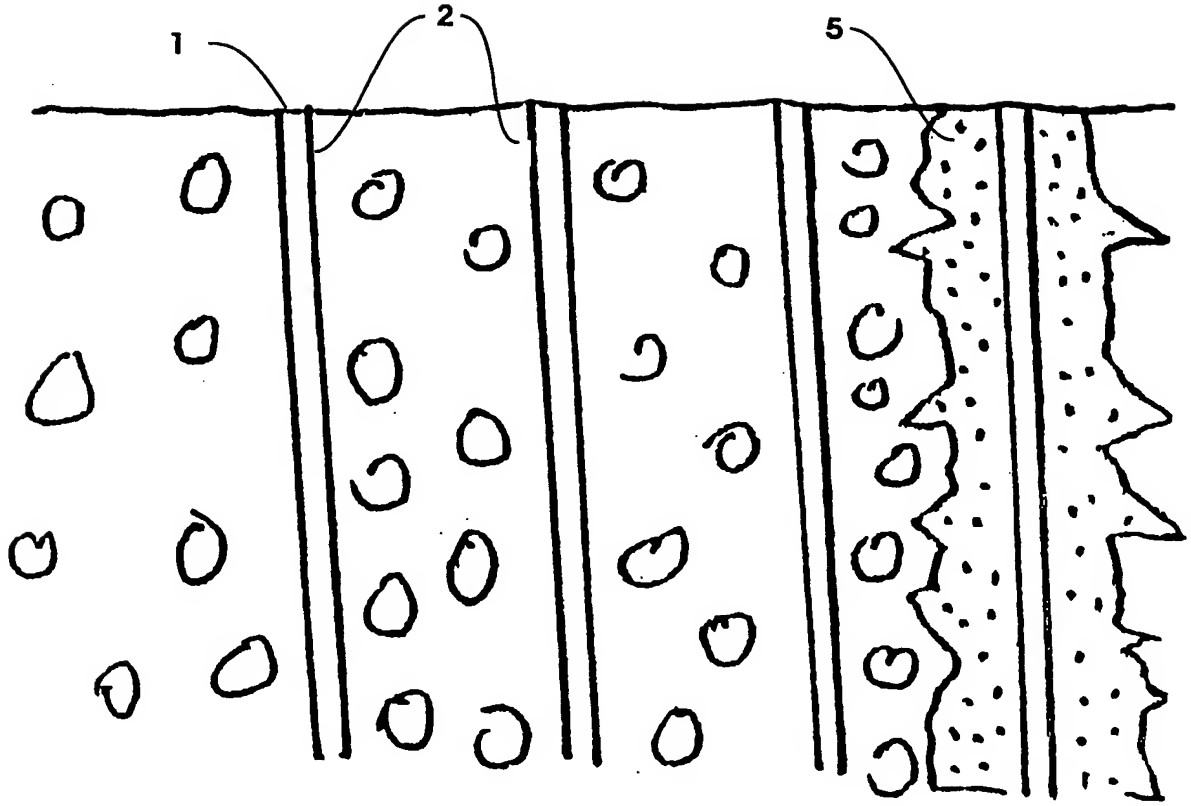


Figure 5

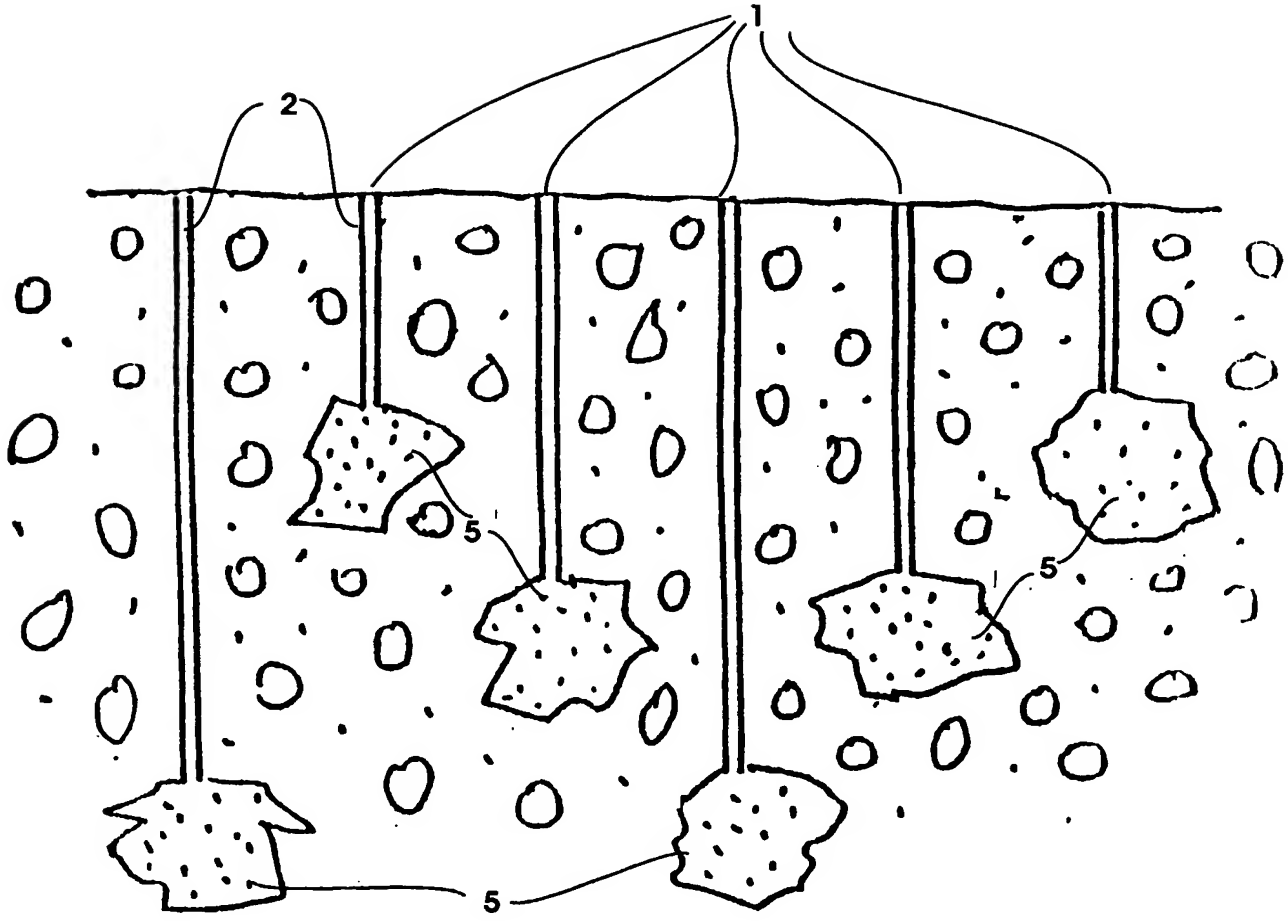


Figure 6

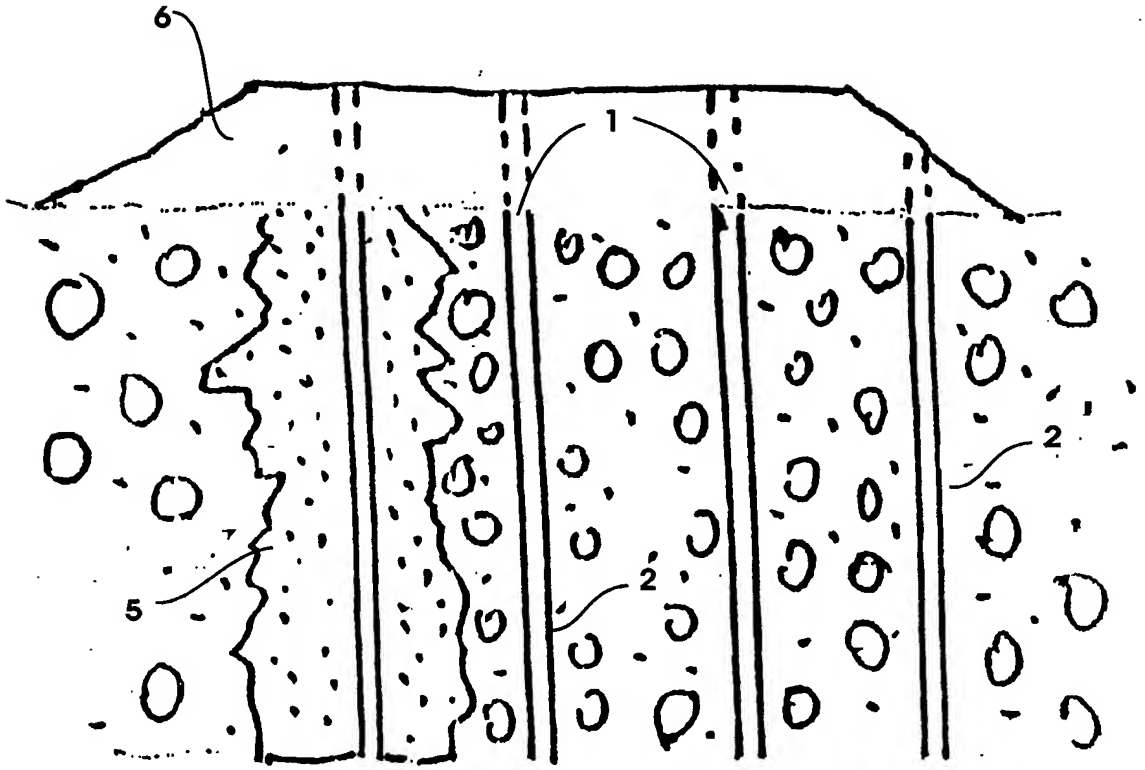
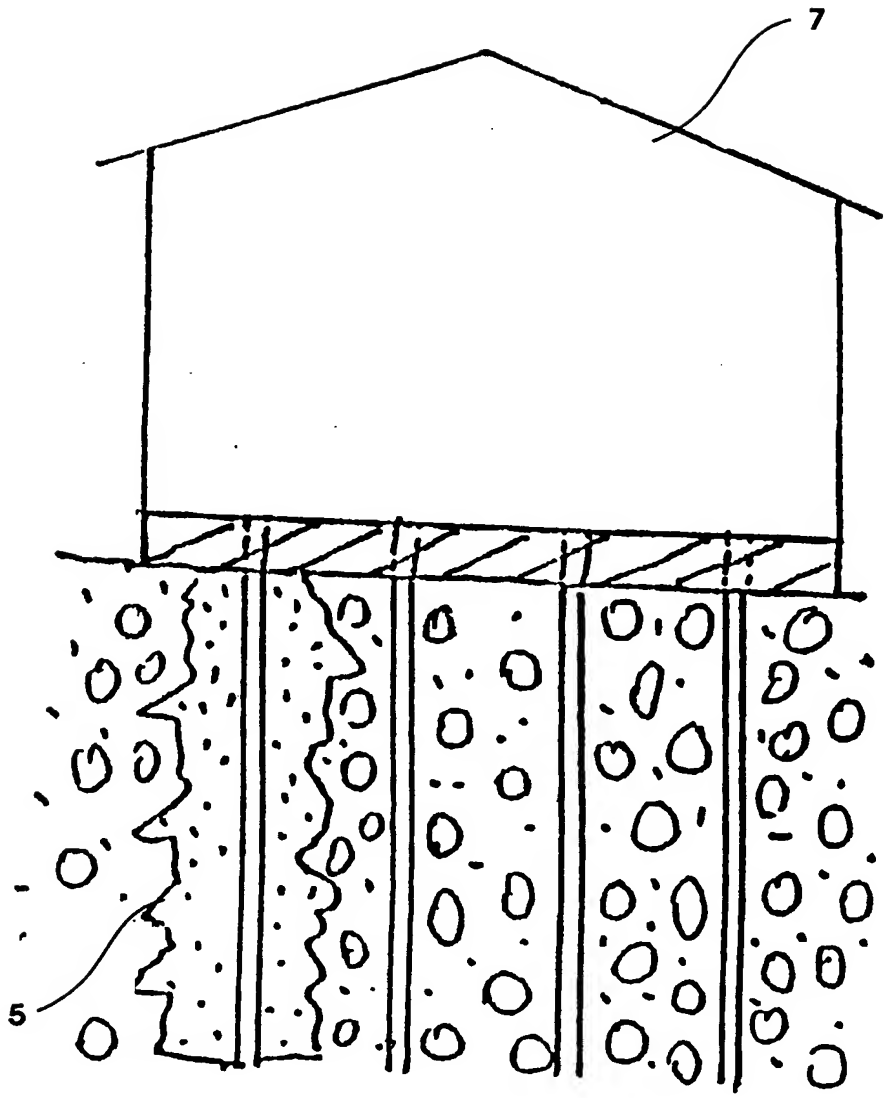


Figure 7



INTERNATIONAL SEARCH REPORT

International Application No
PCT/[redacted]03/00083

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E02D3/12 E02D27/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 E02D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 773 328 A (TAKAO ENTERPRISE CO LTD) 14 May 1997 (1997-05-14) column 2, line 35 - line 57; claim 1; figure 1	1-10,12, 13
Y	EP 0 851 064 A (URETEK S R L) 1 July 1998 (1998-07-01) column 2, line 49 - column 6, line 11; figures 1,4	1-10,12, 13
A	US 2 627 169 A (POULTER JOHN W) 3 February 1953 (1953-02-03) figure 4	11
A	US 4 832 533 A (RINGESTEN BJOERN) 23 May 1989 (1989-05-23) abstract; figure 1	1,2,5,9, 12

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
25 February 2004	03/03/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	De Neef, K

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

[redacted]tion on patent family members

In [redacted] Application No
PCT/IR 03/00083

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP 0773328 A	14-05-1997	JP	9143973 A	03-06-1997
		CA	2190212 A1	14-05-1997
		CN	1156777 A	13-08-1997
		EP	0773328 A1	14-05-1997
		JP	9195257 A	29-07-1997
EP 0851064 A	01-07-1998	IT	1286418 B1	08-07-1998
		AT	181384 T	15-07-1999
		AT	250170 T	15-10-2003
		AU	731637 B2	05-04-2001
		AU	5751998 A	29-06-1998
		CA	2273345 A1	11-06-1998
		DE	69700280 D1	22-07-1999
		DE	69700280 T2	04-11-1999
		DE	69724994 D1	23-10-2003
		WO	9824982 A1	11-06-1998
		EP	0851064 A1	01-07-1998
		EP	0941388 A1	15-09-1999
		ES	2132983 T3	16-08-1999
		GR	3030659 T3	29-10-1999
		HU	0000359 A2	28-06-2000
		JP	2001510514 T	31-07-2001
		PL	186495 B1	30-01-2004
		SI	851064 T1	31-10-1999
		US	2002098042 A1	25-07-2002
US 2627169 A	03-02-1953	NONE		
US 4832533 A	23-05-1989	SE	439793 B	01-07-1985
		CA	1228739 A1	03-11-1987
		EP	0160020 A1	06-11-1985
		GB	2163201 A ,B	19-02-1986
		IT	1181228 B	23-09-1987
		JP	61500365 T	06-03-1986
		NO	852402 A ,B,	14-06-1985
		SE	8305794 A	22-04-1985
		WO	8501763 A1	25-04-1985